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HISTORY AND CONSTRUCTION
OF THE
NORTHERN SUBSTATION
OF THE
BALTIMORE TRANSIT COMPANY

by

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A Paper Prepared as a Requirement for Initiation

for

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SUMMARY

In the expansion of public utilities, the public is generally only acquainted with that part of the service which affects it most directly. The basic functioning of the industry is of the greatest importance to the public but is usually unnoticed.

The development of the street car has been made possible, not only by research, but by developments in economical power systems. Public utilities are inherently best able to serve their customers when unhampered by competition; they are monopoly industries. The chaotic condition of city transportation in Baltimore prior to 1899 was the result of competition among the many existing lines; the consolidation of these independent organizations into the United Railways and Electric Company on March 4, 1899 was the beginning of one of the best transit organizations in this country. To supply the cars with electrical energy most economically called for centralization of power equipment; the merger made this work possible. Losses in long cables when carrying direct current were reduced by the use of alternating current at high voltages, with the subsequent conversion into direct current for the trolleys at substations. The final abolition of all generating plants in favor of wholesale purchase of power from the Baltimore Consolidated Gas and Electric Company was to be expected in the line of increased economy.

Northern substation is not unusual; it is neither the first substation constructed nor is it the latest; it is not the largest plant and is not the smallest; its true importance lies in the fact that it marked a step forward in the development of an efficient, economical and dependable transit organization.

Northern substation was built on Harford Avenue at Holy Cross Lane to strengthen the lines in the northern section of the system; intended as a 4000 KW plant, the original building, now known as number one house, was completed early in 1905 but did not begin operating under full load until July 7, 1906. The station was found inadequate as soon as it began operating, and an additional building, now known as number two house, was constructed in 1907. The second structure was a three-walled building built upon the north wall of the original house and in it two 1500 KW rotary converters were originally installed and operation began in the fall of 1907. The total capacity of the station at this time, therefore, was 7000 KW.

Converter No. 7, a 2000 KW unit was placed in operation June 15, 1912 because of an increased load expected from the Democratic National Convention, which convened in Baltimore that year. An eighth unit, the largest in the plant, having a capacity of 3000 KW, was installed to take care of additional increase of load in the northeastern section of the city; this converter began operation in November, 1918.

To avoid power losses in the long lines leading from Northern to the Hamilton section, it was decided to build a semi-automatic substation in that section. This station was designed to be operated by one man, working only part-time, and capable of being removed from operation by switches at the Northern substation. This station was completed in September, 1929; of the two rotaries installed there, one is a 2000 KW unit removed from Northern, and the other is a 1125 rotary removed from Central substation.

Thus Substation Number 4, Northern, now has a rotary converter capacity of 10,000 KW and operates twenty-one and one half hours every day. Never since its construction has there been a total shutdown of the plant while scheduled for operation. The continual, monotonous hum of the converters heard by passers-by seems to indicate dependability and power. "Street car service must be maintained" they whine.

The History and Construction of the Northern Sub-station of the Baltimore Transit Company.

Progress in industry has been so tremendous in the past century that it is hard to comprehend the vast amount of capital involved in the continual improvement of methods of operation. This is especially true in those industries commonly known as public utilities. In this category are included organizations serving the public with water, gas and electric supply, transportation, and communication--services vital to the general populace. The public demands dependable, economical and efficient service from the utilities, and in order to comply with this demand, they have continually had to expand and improve their plants. Improvements in equipment and methods of operation have continually been utilized.

Many advancements in service have escaped the notice of the public; publicity is given only to that equipment which most closely affects the customer. Many examples of this could be cited: the streamlining of locomotives, air conditioning of cars, and improvements in sleeping cars have been widely advertised while equally important developments in signal equipment, driving machinery, and "velvet" rails have escaped notice. Similarly, the public has been made to notice the new Presidents' Conference Comittee cars by widespread advertisement. However, there is a great difference

in the mere passing of one of the new cars through the streets and the extensive mechanical, supervisory, and power factors that stand back of that car.

The history of the street car of today is more or less well known; numerous papers have been written on the subject. Baltimore has had a leading part in this development; this city saw the first commercially operated electric street car in the world make its maiden run from Oak and Twenty-fifth Streets to the Woodbury terminus on August 10, 1885. This car operated on a third rail system and the locomotive and car are illustrated in figure 1. The line operating this trolley car was the Hampden branch of the Baltimore Union Passenger Railway, a horse-car line.

In spite of the successfulness of this demonstration, the transit industry was still skeptical of electric power as a means of propulsion and on May 23, 1891, the first cable-car line in Baltimore began operation on Druid Hill Avenue. This type of road was operated by means of an endless steel cable running on sheaves within conduits constructed between the rails; a gripping device held the cable at the "gripman's" will and moved the coach forward. This car was doomed to a short life because of numerous cable fractures and improvements in electrical propulsion equipment and much capital invested in such roads was lost. Figure 2 illustrates such a car.

To the casual observer, this history of the street

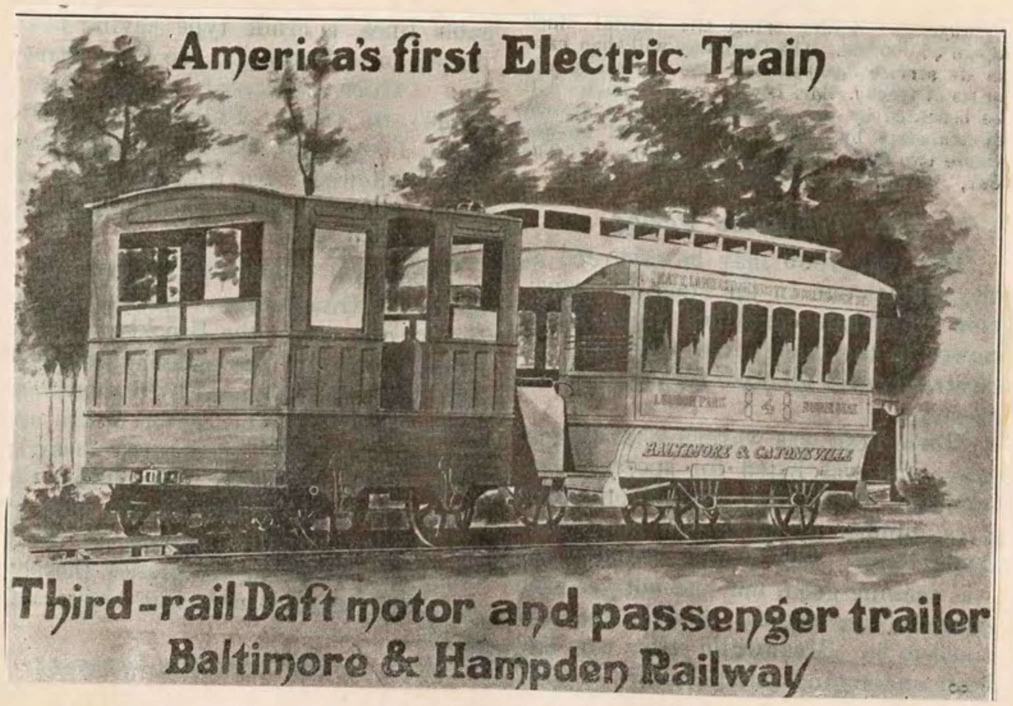

Figure 1.

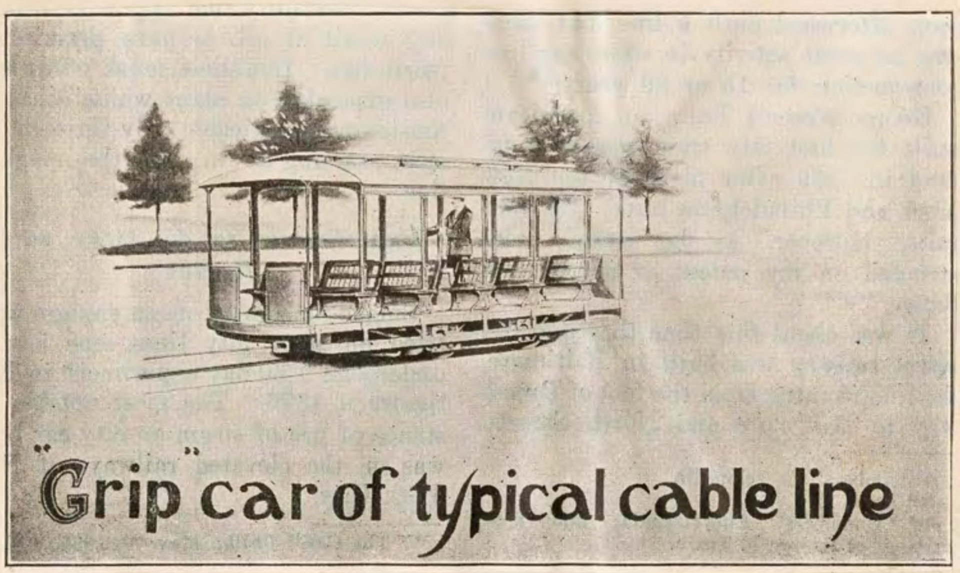

Figure 2.

car itself is a history of the transit industry; however, the important factor of power supply has had an important effect on the growth of the industry. Developments in power supply to the trolleys should be included in any history of electrical transportation.

POWER SUPPLY DEVELOPMENT

From the time of the first electric railway line in Baltimore to 1899 many independent lines were built in the city. Each of these systems suppled its own power from steam-operated generation stations located in strategic positions along the lines. The combined capacities of these plants was greater than the maximum demand at any time of all the lines; a single generation station of smaller capacity could have supplied the entire load at much greater economy. The advantages of joint control of such an industry soon became apparent and on March 4, 1899 a merger of all Baltimore companies was accomplished. The new organization was known as the United Railways and Electric Company.

Since United was formed as a combination of several independent, self-supporting companies, it possessed numerous power plants in various parts of the city. The wastefulness of such an arrangement soon became apparent.

United immediately began the centralization of equipment to a central power plant with auxilliaries as needed.

The inefficiency of transmitting direct current over long lines to outlying sections was obvious and it was decided to generate power as alternating current in the central station and subsequently convert this to direct current for the trolleys in converter substations to be located in strategic parts of the city.

A large power plant located on Pratt Street was enlarged and altered to act as the central power station. In line with the development of transmitting power as alternating current at high voltages, the first converter substation was constructed on Druid Hill Avenue in 1903. This was followed in short order by substations at Nunnery Lane and at the main generating station on Pratt Street.

Thus in 1904, the transit system was supplied with power as follows: Power plants at Pratt Street, 15,600 KW; Light Street, 2,000 KW; Falls Road, 2,250 KW; Bear Creek, 675 KW; Black River, 424 KW; Gilmore Street, 550 KW; and Carey Street, 600 KW. This gave a total capacity of 23,-849 KW. The capacities of the substations were as follows: Druid Hill, 4,500 KW; Nunnery Lane, 1,500 KW; Dugan's Wharf (Pratt Street), 3,000 KW. Another plant owned by United and located on Charles Street was abandoned in November, 1903 and leased to the Herald Publishing Company. This arrangement could satisfactorily supply necessary power

for the 353 miles of track being operated, but was awkward and unsatisfactory from an economic point of view.

BEGINNINGS OF NORTHERN SUBSTATION

In order to eliminate several of the less efficient power plants, contracts were let for two additional substations. Eastern substation, a 3,000 KW converter station was completed in September, 1905 at a cost of $94-614.64. This station was located on Fifteenth Street and Eastern Avenue and began operating on February 27, 1906.

On June, 1905, the United Railways and Electric Company accepted a bid from J. Henry Miller to construct the building for a fifth substation, to be located on Harford Road. The cost of the building was $19,764.84 and it was completed early in 1905. This building was of red brick construction and was designed to house four rotary converter units. The basement was constructed so that the passages served as air ducts for conducting the cooling air from blower to transformers. A balcony was provided for mounting the high-voltage oil switches and cables leading to them in order to keep this dangerously high voltage equipment away from employees. Ducts were built in the front wall for the emergence of cables to the trolley structure.

The necessity for Northern Substation, as the Harford Road plant is called, was expressed in the general

manager's report for the year 1904:

> "To strengthen the lines in the northern section of our system, a fifth substation will be constructed in the vicinity of North Avenue and Harford Road."

The exact site obtained was on Harford Road at Holy Cross Lane, a short distance north of North Avenue.

The contract for the electrical equipment for the substation was taken by the General Electric Company with a price of $178,447.00. Four rotary converters were installed in the plant. Each machine is rated at 1,000 KW and operates at a speed of 375 revolutions per minute. The machine is wound to operate on 25 cycle alternating current at 430 volts and utilizes six phase power. The direct current side of the armature is rated at 575 volts. Each rotary has three air-cooled 375 KW General Electric transformers; these transformers step the voltage down from 13,200 as received from the alternating current feeders to 430 volts for the armature of the converter; each transformer is tapped at the third points so that lower voltages for starting purposes are available. Since the rotaries of this model are unable to start themselves, each has a three-phase, 430 volt, 100 horsepower motor mounted on the armature shaft for starting purposes.

The high voltage cables feeding Northern substation

from the Pratt Street generating station were installed in the city subway as far as North Avenue, and a twenty-four duct subway was constructed from North Avenue to the sub-station at a cost of $4,000. The cable for this run is a three-conductor, oil-filled type purchased from J. A. Roebling for a price of $25,885.

The high-voltage cable runs through ducts to the oil switches, which, as stated before, are mounted in a special balcony. The switches are made by the General Electric Company and are rated at 300 amperes and 15,000 volts. Since this power is three-phase, 13,200 volts and the converters are six-phase, 430 volts, a diametrical connection, with transformer primaries connected in delta, is used to impose the alternating current upon the converter armature. Diagram one ? illustrates this connection.

For cooling the transformers, air is delivered through basement ducts at a pressure of one ounce per square inch. This air is circulated by a Buffalo Forge Company twenty-five inch blower with a circulating capacity of 20,-000 cubic feet per second; this blower is operated by a General Electric three-phase, twenty-five cycle, 350 volt, 7.5 horsepower motor which operates at 500 revolutions per minute. The blower is illustrated in figure 3.

The station is equipped with a complete switching apparatus, with indicating and measuring instruments.

Fig. 3.

A View of Rear of Station
Showing Blower in Background.
The Oil Switches are Visible
in the Foreground.

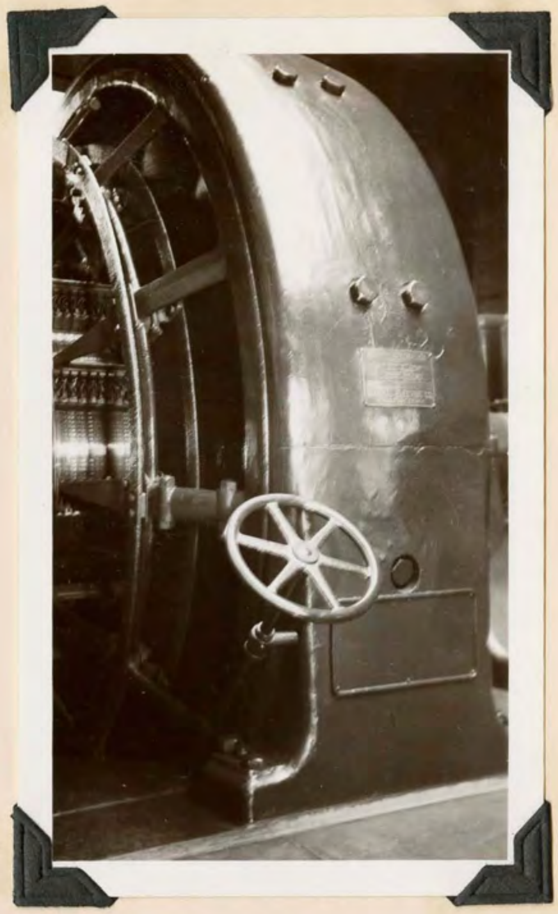

Fig. 4.

Rotary Converter No. 1.
Capacity--1,000 KW.
Installed July 7,1906.

Fig. 5.

Northern Substation Today; No. 1 House on Right.

Fig. 3.

A View of Rear of Station
Showing Blower in Background.
The Oil Switches are Visible
in the Foreground.

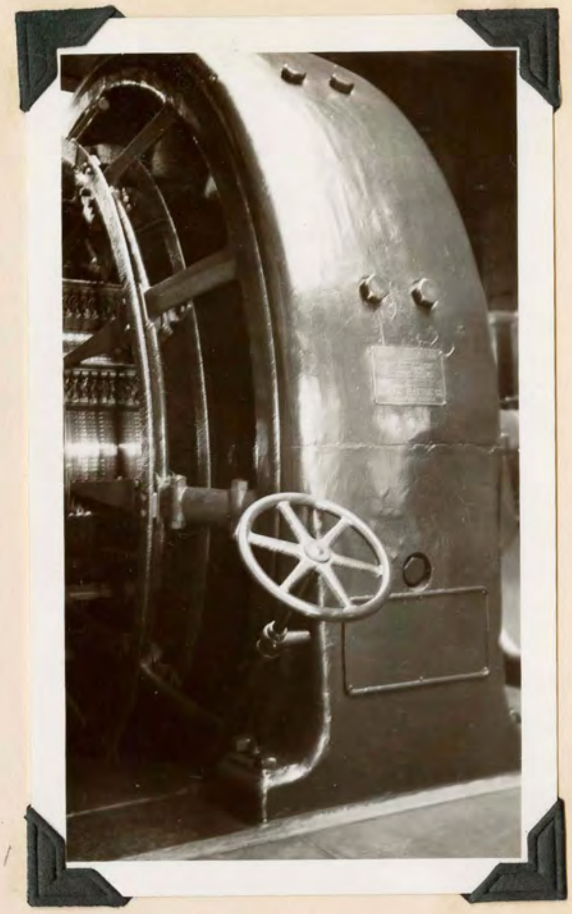

Fig. 4.

Rotary Converter No. 1.
Capacity--1,000 KW.
Installed July 7,1906.

Fig. 5.

Northern Substation Today; No. 1 House on Right.

The instrument board consists of two sections--an alternating current section containing relay switches for the oil switches and metering devices, and a direct current section containing switches for placing various sections of the line on the bus bars of the station and meters for measuring the current and power being drawn. Figures 6, 7, and 8 illustrate the panel board of the station.

The relays for operating the oil switches are operated by a sixty cell, 130 volt battery which floats across the bus bars through suitable resistors. These cells are of the Exide type.

NUMBER TWO HOUSE

This first unit of Northern substation was overloaded from the time it began operation and an addition became essential. The report of the general manager in 1907 said:

> "As the original installation of Northern substation was inadequate to carry the load of the sections supplied by it, it was considered advisable to construct an addition to this station, to be known as Northern Number Two, and the lot adjoining Number One Station was acquired for this purpose."

This additional building was completed in November 1907 and equipped with two 1500 KW rotary converters and necessary transformers and auxiliary apparatus. An additional three-

Fig. 6

Alternating Current Panel, showing instruments and relay switches for oil switches.

Fig. 7.

Direct Current Panel, showing instruments and switches for various lines. Circuit breakers can be seen above ammeters.

Fig. 8

Newer section of Direct Current Panel.

conductor high tension cable was installed from Pratt Street to this station for the purpose of taking care of the additional load on this substation. The combined capacity of these stations was 7000 KW and they were operated from a single panel by a single group of operators. The station was now capable of adequately supplying power to the entire northeastern section of the system, including the outlying sections of York Road, Towson, and Belair.

The new building was a three-walled affair built upon the north wall of the original building. The architecture of both houses is identical. Number Two house was constructed without a balcony for the oil switches to allow the mounting of a Mars twenty-ton crane, a machine omitted in the original building and sorely needed. The oil switches in the new house were mounted on the main floor..

The two rotary converters originally installed in the new building were identical, being General Electric machines of 1500 KW capacity. The alternating current side of the armature is designed for twenty-five cycle current at 430 volts, while the direct current side is rated at 600 volts. The speed of the machine is 250 revolutions per minute. Transformers of similar make and rated at 550 KVA, with a voltage ratio of 13,200 to 430 were installed for the converters. These transformers are also air-cooled and tapped at the third points for starting purposes. The converters are self-starting.

Fig. 9.

Converter No. 6.
Capacity--1500 KW.
Installed October 12, 1907

The oil switches of No. 2 House.
300 amperes, 15000 volts.

CENTRALIZATION OF POWER STATIONS

After the construction of Northern substation, and the transfer of two additional units to Pratt Street generating plant from abandoned plants, it became possible to close down the outlying plants at Bear Creek, Preston Street, Carey Street, Gilmore Street, Light Street, Falls Road, and Owings Mills, each of which was generating current at a cost greatly in excess ~~to~~ of that at Pratt Street.

The report of the general manager for 1907 states:

> "The rehabilitation of the Company's power plants and distributing system has made it possible to shut down the following direct current, steam driven power stations: Gilmore Street, Carey Street, Bear Creek, Back River, and Preston Street. From these plants the necessary equipment for the Bay Shore power house was obtained."

Bay Shore power house was constructed in 1907 to supply light and power to Bay Shore Park since it was more economical to build this station, using equipment from abandoned plants, than to run feeders from Eastern substation. This was a 1175 KW plant, meager in comparison to the 25,000 KW capacity of Pratt Street at this time. This was the last power plant built by United.

In 1908, the Falls Road plant was damaged by fire. It was deemed advisable to close down and abandon the plant

as soon as cables could be run to Northern substation. Thus in 1909, the capacity of the Pratt Street plant was 39,400 KW and the only other station in operation was the Bay Shore power plant, used only for service during the season when the park was open. The Owings Mills station was kept in operating condition but unused.

Thus within a period of ten years, the power supply system of the United Railways and Electric Company had changed from a wasteful system of numerous generating plants to a centralized power system. It then could be supplied with additional hydro-electric power from the McCall Ferry plant of the Pennsylvania Water and Power Company by running high tension cables of the power company to the Pratt Street plant. The first contract for additional power was signed in 1911 when 12,000 KW were to be supplied. In that year, the United purchased 45,174,700 KWH from the Power company, and generated 63,003,722 KWH at their Pratt Street plant. This amount being supplied by the Power company was gradually increased until the Pratt Street station was operated for emergency service at power failures of the Pennsylvania Water and Power Company. In 1921, Consolidated Gas and Electric Company, an affiliate of the Power company, purchased the Pratt Street plant and United bought all of its power from that company. Thus United left the generation of electricity to a company specializing in electric power supply.

LATER CHANGES AT NORTHERN SUBSTATION

In 1911, an 125 KW booster, motor driven, formerly used at the Falls Road power plant was placed in regular service at Northern to boost the voltage on the line supplying the Towson section. This line is twelve miles long and the booster is adjusted to boost the voltage one quarter volt per ampere of load current. This booster set contains a Westinghouse 125 KW, 265 volt, 470 ampere series generator driven by a Westinghouse 500 volt direct current, 250 amperes, 530 revolution per minute motor. (Fig. 11.)

In order to increase the capacity of Northern substation in 1912 to take care of extra demand expected on account of the Democratic National Convention held that year in the city, an additional 2000 KW rotary converter was installed in that substation June 15, 1912. This was a Westinghouse machine, converting twenty-five cycle alternating current at 430 volts to 575 volt direct current. The rotary operated at a speed of 375 revolutions per minute. Three 750 KVA transformers of the same make were used with the machine and the diametrical method of imposing three phase current on a six phase machine was utilized.

In 1913, city ordinances demanded the removal of cables from overhead structures and the switchboard at Northern was rearranged to permit the direct current cables to leave the building through underground ducts. The work was completed by

October 2, 1914.

By 1917, the track mileage had increased to 414.87 miles. In order to operate the new lines of rails and to be able to supply the additional load on the system due to increased business activity in plants manufacturing war materials, it became necessary to further increase the capacity of Northern substation. A 3000 KW rotary converter with three transformers was purchased from the Westinghouse Electric and Manufacturing Company for a price of $36,500. Shipment was delayed due to war conditions and the machine was not installed until 1918. Operation began November 30, 1918.

The ratings of this machine, the largest installed at Northern, called for twenty-five cycle alternating current at 430 volts. The rotary operated at 250 revolutions per minute and the direct current side of armature is rated at 600 volts and 500 amperes. The three transformers used with this converter are each rated at 1125 KVA and are of the air-cooled type. The high-voltage switchgear for use with this machine was purchased from the General Electric Company at a cost of $10,700. Figures 13 and 14 show two views of this rotary converter.

In 1921, a plan was worked out for improving voltage conditions on the outlying Towson and Carney sections by using Number Four converter at an eighty volt increase at

Fig. 12.

Series Booster of Number 1 House. Capacity--125 KW.

Fig. 13.

Number 8 Rotary Converter. 3,000 KW, 600 Volts d. c. Westinghouse manufacture.

peak hours. The necessary additional bus structure was installed. This method of maintaining two bus-bar voltages proved satisfactory and it was decided to make the arrangement permanent. Additional bus structures were installed and Converters Numbers One, Two and Three were adjusted to deliver 610 volts to the high-voltage bus. The other machines maintained the voltage on the original busses at the normal value or 585 volts. Proper switching arrangements made it possible to switch the Towson, Gorsuch Avenue, and York Road lines to either set of busses as desired. The booster could also be inserted in the Towson and York Road lines to further boost that voltage if need arose.

No important changes were made in Northern Substation until the rapid development of residential areas served by the Belair Road, Harford Road, and Carney lines overloaded the power facilities there in 1928. Plans were started in that year for an additional substation in the load center of that area. The site finally selected was on White and Carter Avenues, Hamilton. Much spare capacity was available in existing substations so it was decided to use equipment already on hand in the new substation.

Since the new substation was in a residential section of the city, it was decided to build it in a type of architecture fitting for the surroundings. In order to economize on additional operators, it was planned to make

Hamilton substation, the name given to the new plant, semi-automatic, capable of being operated by one man working only part time. The estimated cost was $135,000.

The new substation was completed in 1929. It was supplied with power by two high-tension, three-conductor cables from Northern substation, and the two rotaries installed there were transferred from existing plants. One of the machines, a 2000 KW. Westinghouse machine, was moved from Northern Substation where it had been serving as Number Seven converter. The other converter for Hamilton was a 1125 KW machine removed from Central substation.

The switchgear formerly used with the converter while in operation at Northern was now utilized on the high-tension cables feeding the Hamilton station. Thus it became possible to take the new station out of operation by merely opening the oil switches at Northern. However, this station can not be placed into service from remote control from the servicing station and requires an operator for that purpose; for this reason it is considered a sem-automatic station. The operator is present during the peak hours of the morning and leaves the machines in operation, knowing the operators at Northern will cut them out as the load drop makes their operation unnecessary.

Some trouble developed at Northern in the failure of operators to realize when circuit breakers on the various

lines had opened until power had been off for a period of time. Consequently, a system of signals, whereby a horn sounds in the plant whenever any circuit breaker opens, was installed.

RETROSPECT

From the above discussion, it is obvious that Northern substation now has a rotary converter capacity of 10,000 KW and an additional capacity from booster sets of 325 KW. It is served by four high-tension cables which deliver alternating current at 13,200 volts from the Pratt Street switching house of the Consolidated Gas and Electric Company. This company generates this current as hydro-electric power in its stations at Westport and Holtwood. Northern supplies power for the trolleys serving northeastern Baltimore; the exact lines served can be seen on Diagram 2 which shows a schematic diagram of the entire plant, including both houses. It also relays the high voltage power supply to a semi-automatic substation in Hamilton and possesses the necessary oil switches for taking this substation out of service. Diagram 3 shows the exact location of both Northern and Hamilton substations as well as the general section of the city served.

The Baltimore Transit Company now owns and operates

Fig. 14

Rotary Converter No. 8
Westinghouse Manufacture
Capacity--3,000 KW.

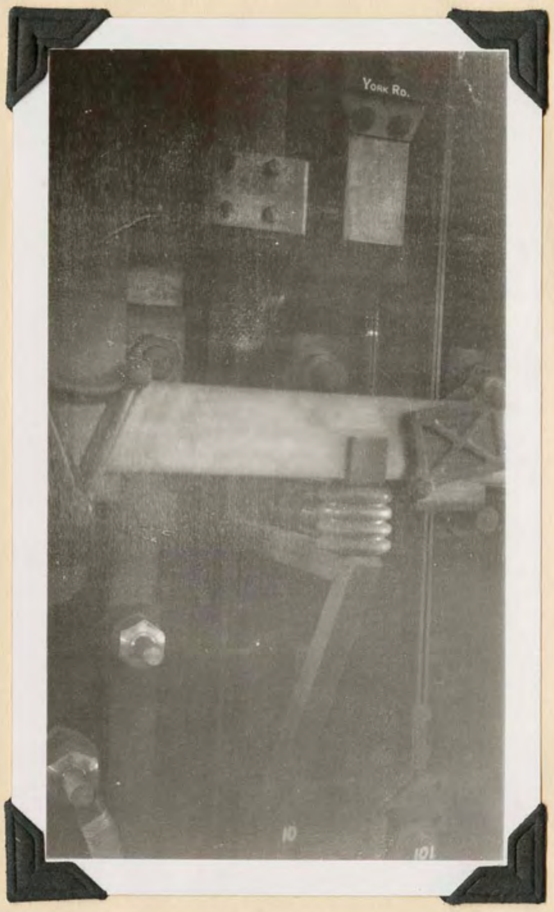

Fig. 15

A view of the rear of the
direct current panel, showing
610 volt busses and feeder to
York Road.

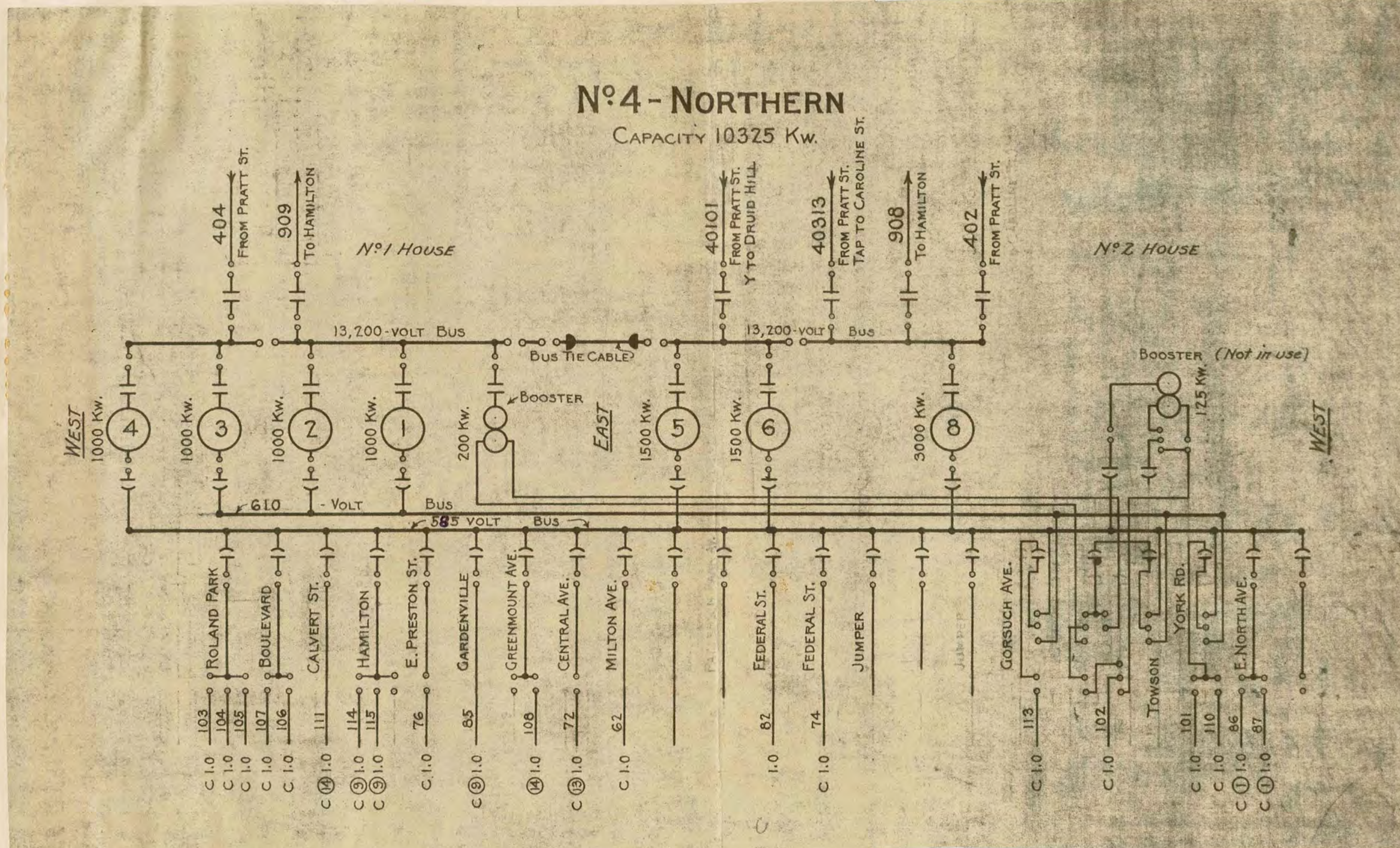

Diagram 2.

A schematic diagram of the layout of Northern Substation showing connections of machines, feeders, and distribution lines.
Note especially the two direct current busses, 585 and 610 volts.

476 miles of street car track. The electrical energy consumed in 1937 totaled 128,271,436 KWH, all of which was purchased from the Consolidated Gas, Electric Light and Power Company. This energy in the form of alternating current at 13,200 volts was transformed into direct current within the thirteen substations owned and operated by the Transit company.

CONCLUSION

As the street car being operated in Baltimore grew from the rambling mechanism which made its initial run on the streets of Baltimore in 1885 to the Presidents' Conference Committee car of 1937, the equipment and method of power supply developed also. The uneconomical production of current in many small power stations gave way to the central power plant system. This in turn gave way to the use of hydro-electric power, purchased from the Consolidated Gas, Electric Light and Power Company, thus eliminating the capital involved in electrical production from the investment of the Baltimore Transit Company. The present organization whereby current is purchased at 13,200 volts, alternating current, and transformed into 600 volts direct current in efficient converter stations has given the residents of Baltimore dependable, economical transit service of both trolley cars and coaches.

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